IAQ AND CFD STUDY ON THE VENTILATION SYSTEM IN A CHASSIS DYNAMOMETER ROOM

ALAEDDIN MOHAMED EJLEDI

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

ALAEDDIN MOHAMED EJLEDI

A thesis submitted in fulfillment of the requirement for the award of the

Degree of Master of Engineering

Faculty of Mechanical and Manufacturing Engineering

University Tun Hussein Onn Malaysia

MAY 2011

DEDICATION

I dedicated this thesis to my parents. Without their patience, understanding support and most of all love, the completion of this work would not have been possible.

ACKNOWLEDGEMENT

The special thank goes to my helpful supervisor Dr.SAFIAH BINTI OTHMAN Great deals appreciated go to the contribution of faculty of mechanical and manufacturing engineering I also would like to thankful the Coordinator of mechanical engineering Dr Maizlinda Izwana Idris that the patient in helping us complete this program , and for the smoothes and co-operation during the visited.

Last but not least I would like to thank my friends especially those who work together as interns at university Tun Hussein Onn .

Abstract

The chassis dynamometer room is one of many extensions in the automotive laboratory, UTHM, which is one of a few dynamometer rooms available in Malaysia. Consequently, it becomes highlighted facility to do tests and researches with respect to vehicle components such as the braking, cooling, and electrical systems. The major application however is to evaluate engine performance. Ventilation system is an essential system to reduce the air pollution, thus maintain acceptable indoor air quality (IAQ) in any chassis dynamometer room. Currently, the room depends on two types of ventilation: natural ventilation through two windows and a door, enhanced with mechanical ventilation which is an exhaust fan placed on the top of the room. Unfortunately, the existing ventilation system is not sufficient to support activities conducted in the room as was proven in the IAQ study. Therefore in the current study, results of a computational fluid dynamics (CFD) for air flow and thermal distribution in the tested room are presented. CFD results expose the weaknesses of the existing system. Thus, a much better air flow structure and thermal distribution as required shall be provided by the installation of a new improved ventilation design as proposed in this study.

Abstrak

Ruang chassis dynamometer merupakan salah satu lanjutan yang banyak di makmal otomotif, UTHM, yang merupakan salah satu ruang dinamometer yang terdapat di Malaysia. Akibatnya, ia menjadi kemudahan yang terserlah untuk diuji dan dikaji dalam kaitannya dengan komponen kenderaan seperti brek, pendingin, dan sistem elektrik. Namun, aplikasi umumnya ialah untuk membuat penilaian terhadap prestasi enjin. Sistem Pengudaraan merupakan sistem penting untuk mengurangkan pencemaran udara, sehingga menjaga kualiti udara yang boleh diterima dalam ruang (IAQ) di setiap ruang dinamometer chassis. Pada masa ini, ruang bergantung pada dua jenis pengudaraan: pengudaraan semulajadi melalui dua jendela dan pintu, dipertingkatkan dengan pengudaraan mekanikal yang merupakan exhaust fan diletakkan di atas ruang. Malangnya, sistem pengudaraan yang ada tidak cukup untuk menyokong kegiatan yang dilakukan di ruangan tersebut sebagaimana terbukti dalam kajian IAQ. Oleh kerana itu dalam kajian ini, keputusan pengkomputeran dinamik bendalir (CFD) untuk aliran udara dan pengedaran panas di ruangan itu dipersembahkan. Hasil daripada CFD mendedahkan kelemahan sistem yang sedia ada. Dengan demikian, struktur aliran udara yang jauh lebih baik dan pengedaran terma yang diperlukan hendaklah disediakan oleh pemasangan rekabentuk pengudaraan yang baru diperbaiki seperti yang dicadangkan dalam kajian ini.

CONTENTS

CHAPTER 3 INDOOR AIR QUALITY STUDY

CHAPTER 4 NUMERICAL METHODOLOGY

.

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

G	-	Mass flux
pa	-	Paschal
V	-	Volume
Δ	-	Change in parameter
T	-	Temperature
L	-	Length
D_{eq}	-	Equivalent diameter
R_e	-	Reynold's number
Pr	-	Petukhov correlation
α (^{o})	-	Helix angle
w	-	width
q	-	Heat flux
f	-	Frictional factor
$\boldsymbol{\phi}$	-	Pressure drop
E	-	Electric Voltage input
q_E	-	electric power inlet
I	-	Electric current through test channel
t	-	time
H	-	Heat
ζ	-	Efficiency

CHAPTER 1

INTRODUCTION

In today's, with the ever-increasing emission of noxious gas and fumes from industrial sites, the issue of air pollution has become one of the most topical issues. Air pollution is defined in many air pollution control lows as the presence of one or more contaminants, in such quantities and of such duration as they be or tend to be injurious to human life or property. Carbon monoxide (CO) and Carbon dioxide (CO2) are highly toxic gases (K. Papakonstantinou *et al*., 2003).

CO has no colour, no smell, emitted as a product of incomplete combustion of hydrocarbon based fuel coming from the car exhaust and burning of coal or wood, the most dangerous types of air pollution and the most toxic to human and animal. When inhaled, CO binds reversibly with blood haemoglobin to form carboxy-haemoglobin, impairing the oxygen-transport of the blood, as well as the oxygen's release to body tissues, causing therefore severe and even fatal asphyxiation, CO2 consists of carbon dioxide from the combustion of organic materials such as paper, wood, coal and oil. The carbon dioxide resulting from fuel from the most important pollutants introduced by the air rights and lead to increased difficulty in breathing with irritation of the mucous membranes and inflammation of the bronchial and throat irritation.

However, there is an increasing demand for indoor concentration measurements, especially indoor workplaces with high-expected CO2/CO concentrations (K. Papakonstantinou *et al*., 2003). The indoor workplaces have been reported as an important determinant of exposure to CO/CO2. Insufficient or malfunctioning ventilation inside, allows contaminated air to accumulate, and pollutant concentrations to increase.

This accumulation of contaminant may cause damages to employees' health, taking into consideration that exposure to CO/CO2 covers all their working day. The problem of indoor air quality gives rise to questions concerning the arrangement of fresh air supply. Processes involved in ventilation are the most important in determining the quality of indoor air. It is important to get adequate mixing of inlet air with room air, in order to obtain a uniform fresh air distribution. The evolution, during the last decade, of a large number of multi-dimensional, multiphase models and solutions techniques for simulating fluid flow and concentration dispersion processes has made it possible to use new computational fluid dynamics methods to assess the effectiveness provisions in buildings

However, in this study we concentrated on chassis dynamometer room which is the standard tool for legislatively prescribed emission tests. For emission testing and many other vehicle test purposes the dynamic response is an adequate approximation to ‘on road’ conditions. This is not necessarily true if the requirement is to study vehicle driveline dynamics. Also we can say that chassis dynamometer room extremely useful for testing the effectiveness of vehicle modifications. It’s a near-ideal environment to perform back-to-back comparisons of different camshafts, turbochargers and just about any engine upgrade you can mention. A chassis Dynamometer room is also a great place to hold an engine at a specific load/rpm site to perform engine management tuning; also commonly used for fault-finding and speedometer calibration.

In the test vehicle will result in out hot smoke contain harmful gases (carbon monoxide and carbon dioxide). These gases will increase the room temperature and indoor air pollution of the dynamometer room. In this case we need a good ventilation system provided to evacuate the room of hot air and exhaust gases and allow cool air to enter for the car radiator.

Furthermore, studies of indoor air quality employing computational fluid dynamics (CFD) are widespread, because CFD is capable of providing precise information on factors including the distribution of flow and concentration. Several indexes of ventilation effectiveness have been proposed and examined with the aid of

CFD. The use of computational fluid dynamics (CFD) to simulate environmental and building problems has been around for over 20 years (Zhang Lin *et al.*, 2006). The majority of building research investigates mainly office, residential and commercial buildings such as office and workshops. In a few cases, public areas have also been simulated such as the case of an indoor auto-racing complex. CFD was used to determine the optimal way to design a ventilation system to prevent vehicle exhausts from cars from reaching spectators. The CFD technique has become an increasingly popular method to determine the indoor environment. Computational fluid dynamics (CFD) makes it possible to simulate airflow patterns, thermal comfort and concentration distributions of pollutants in a space at much less cost. This technique, allowing the simulation and the visualization of environmental problems, represents a powerful tool to motivate, guide and educate about the environment (R.A. Pitarma at el ., 2004). CFD involves the solutions of the equations that govern the physics of the flow. Due to the limitations of the experimental approach and the increase in the performance and affordability of computers, CFD provides a practical option for computing the airflow and pollutant distributions in buildings(Tatsuya Hayashi et *al*., 2002). A more practical approach is to subdivide the space inside the room into a number of imaginary sub-volumes, or elements. These sub-volumes usually do not have solid boundaries; rather, they are open to allow gases to flow through their bounding surfaces (John D *et al*., 2001).

Therefore, the goal of current study is to find the velocity throughout the room, for each of the sub volumes. This will reveal the flow patterns and the pollution migration throughout the room The temperature distribution within the loted is also of concern

1.1 Problem of statement

The chassis dynamometer room in the automotive laboratory UTHM is one of very few chassis dynamometer room available in Malaysia. Therefore, it's considered as a one of rare facilities for test concerning engine performances, fuel consumptions and exhaust emissions. SIRIM for instance, needs the equipment for experiments on new invented biodiesels. The room is already equipped by a ventilation system, but unfortunately this existing system is not sufficient to support activities conducted in the room, as high temperature and accumulated smoke in the room are obviously observed. Hence, the person in charge needs the aid of natural ventilation which is windows and door opening. However, the problem is still occurring. Therefore, health and comfort issues are crucial. Furthermore, reliability of the chassis dynamometer test results could be questioned due to the instability of temperatures and relative humidity in the room during experiments. In order to obtain good results both temperature and relative humidity in chassis dynamometer room shall be maintained at certain constant values during testing. In the present work the Indoor Air Quality (IAQ) in the chassis dynamometer room is has been proved to be poor, leading to hazardous and uncomfortable working environment. Thus, the development of an improved ventilation system is essential. In this study will focus on finding alternative solutions and the development of the ventilation system in the room by using CFD software.

1.2 Objective of study

i) To measure the Indoor air quality (IAQ) in the chassis dynamometer room (Automotive Lab UTHM).

ii) To study the air flow structure and temperature distribution in the chassis dynamometer room (Automotive Lab UTHM) .

iii) To propose a new ventilation system design

1.3 Scope of study

i) Focus on the chassis dynamometer room, automotive lab, UTHM

ii) IAQ study (Mitsubishi carpowerd by diesel in this tested during this study)

iii) Referring to international ASHRAE standard.

vi) CFD study to obtain flow structure and temperature distribution in the room.

1.4 Expected Result

(i) The ventilation system in the chassis dynamometer will be verified to be severely insufficient by means of :

a) IAQ measurement

b) CFD study

ii) An improved ventilation system proposed.

iii) Appropriateness of the proposed designs have been proved by using CFD software.

1.5 Methodology of Study

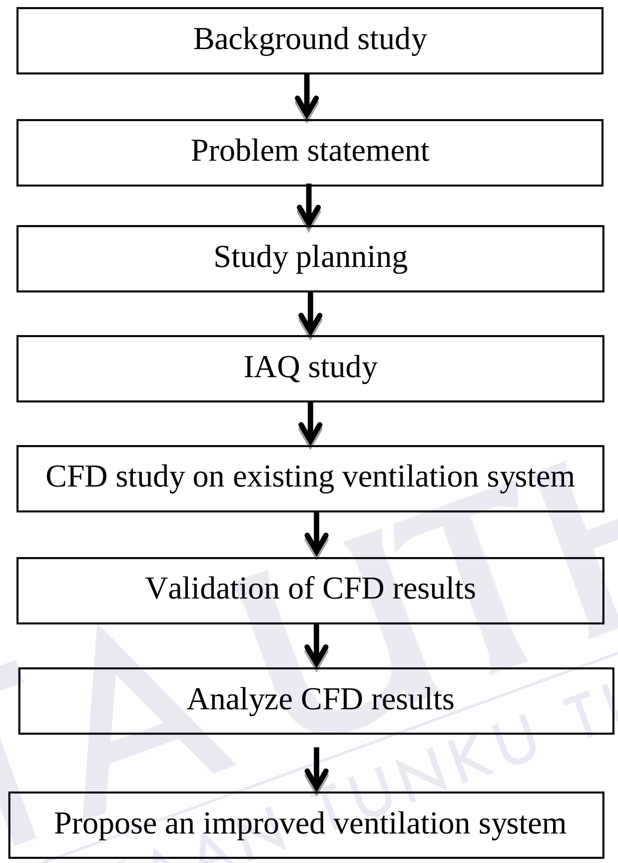

Figure 1.1 Study flow chart

Table 1.1 Gantt chart

DESCRIPTION		1	2	3	4	5	6	7	8	9	10	11	12	13
		Semester 1												
		week												
Background of stud	Target													
	Actual													
Problem statement	Target													
Study planning	Target													
	Actual													
Writing report	Target													
	Actual													
Prepare for presentation	Target													
	Actual													
		Semester 2												
		week												
CFD study on existing ventilation system	Target													
	Actual													
Validation of CFD result	Target													
	Actual													
Analyze CFD result	Target													
	Actual													
Propose an improved ventilation system	Target													
	Actual													
Writing thesis	Target													
	Actual													
Prepare for presentation	Target													
	Actual													

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of literature related to the topic under investigation. In the first part of this chapter, a few researches on the ventilation system are outlined. The second part excerpts the studies carried out on the indoor air quality.

2.1 Ventilation system

Ventilation is a process of introducing fresh air into a space of interest to dilute contamination and to remove excess heating or cooling loads. For building ventilation, the fresh air comes from outdoor or from HVAC (heating, ventilation and air conditioning) systems. In a manned spacecraft, the fresh air comes from Air Revitalization (AR) Subsystem (CO2 and trace contaminants removal), Temperature and Humidity Control (THC) Subsystem (heat and water vapor removal) and Atmosphere Control and Supply (ACS) Subsystem (O2 supply). In space, because of the absence of natural convection, ventilation is also the primary means to remove the heat produced by onboard equipment and the crew and to promote the well mixing of the atmosphere constituents (O2, N2, CO2, etc.) inside the cabin.

In general, the objective of ventilation is to provide a habitat with good air quality and thermal condition that are more suitable for people and processes than what naturally occurs in an unventilated space with lowest possible energy consumption. Therefore, the value of ventilation lies in how well these basic needs are fulfilled. (Peng,1998).A good ventilation system can thus be defined as the one which can provide a habitat with healthy indoor air quality and comfortable indoor thermal condition with as low as possible energy consumption.

(Koji Sakai et al., 2007**).** In Japan, the following of further improvement in the amenity : washable seat, heated seat, deodorization with function stool. In this study, the examination was carried out on the usefulness of the local ventilation system using CFD analysis method on the assumption of the lavatory in office building. In the analysis, it is examined by changing the volumetric exhaust flow rate on ceiling ventilation, local ventilation and ceiling and local ventilation combined use. On each case, it is examined by changing air ventilation balance and outlet position. The result showed that the local ventilation could reduce the indoor pollutant quality concentration in comparison with the ceiling ventilation at little ventilation air volume. And, it was shown that diffusion range of the pollutant to the near human head was reduced **.**

In the individual exhaust system, in which an exhaust opening was installed near a lavatory basin, results showed that concentration of indoor air contaminants could be kept low compared with others. And it was shown that the energy saving by the ventilator volume reduction could be expected by the adoption of this system. Furthermore, when using only ceiling exhaust, it was clarified that the indoor average concentration and the concentration in a respiratory zone were high compared to other situations. Future studies of the influence of rising heat currents near a user and concentration properties with intermittent ventilation are scheduled .

(Duncan A. Phillips *et al*., 2004). discussed the design of ventilation systems for negatively and positively pressurized patient isolation rooms. The paper focuses on how to quantify and achieve target levels of protection for either the patient (positively pressurized rooms) or health care workers and other hospital occupants (negatively pressurized rooms). Attention is paid to the influence of ceiling supply diffuser selection. Thermal comfort issues are also discussed, and an alternative to "age-of-air" techniques using age-of-contaminant calculations is recommended for use in patient isolation room design. Practical considerations are illustrated through the presentation of two case studies. The first case study of a TB isolation room includes a CFD model analysis of different air distribution systems including an assessment of ventilation effectiveness and patient thermal comfort. This work includes simulation of a cough from a patient toward a health care worker and throughout the isolation suite. The second case study of a positive pressure isolation room assesses the throw of supply air around a patient bed in terms of providing protection for the patient while maintaining comfortable conditions.

REFRENCE

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2002. HVAC *Design Manual for Hospital and Clinics*. Atlanta.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2008*. Indoor Air quality guide*.

ASHRAE Standard 55, ASHRAE Standard 62. *Indoor air quality guide* .

Elsafty, A. F (2010) *Ventilation Efficiency Inside a Ship's Cabin Based on Air Diffusion Performance Index* (ADPI). European journal of scientific research. 40 (1)

Lee SC, Li WM, Ao CH, 2001 HK EPD (Hong Kong Environ Protection Department) Indoor Air Quality Information Centre, Hong Kong

Memarzadeh F, Manning A. Comparison of operating room ventilation systems in the protection of the surgical site. *ASHRAE Transactions.* 2002;108: part 2. http://orf.od.nih.gov/PoliciesandGuidelines/Bioenvironmental.

John D. Spengler, Jonathan M. Samet, John F. McCarthy (2001) . *Indoor air quality handbook.*. New York : McGraw-Hill.305.

K. Hooman. 2009 Numerical simulation of ventilation air flow in underground mine workings. *12th U.S./North American Mine Ventilation Symposium 2008 Wallace (ed).*pp 253- 259

Koji Sakai1, Yasutaka Murata2, Ryutaro Kubo3 and Ryoichi Kajiya1 2007 A CFD analysis of ventilation system of lavatory in office building.: *Building Simulation* 2007 .pp. 415- 420.

K. Papakonstantinou, A. Chaloulakou, A. Duci, N. Vlachakis and N. Markatos (2003) Air quality in an underground garage: computational and experimental investigation of ventilation effectiveness. *Energy and Buildings.* 35. (2003).pp 933–940

Indoor environmental quality: Building ventilation," National Institute for Occupational Safety and Health, 2008.

WANG*, L and N H Wong**,** "Coupled simulations for naturally ventilated rooms between building simulation (BS) and computational fluid dynamics (CFD) for better prediction of indoor thermal environment". *BUILDING AND ENVIRONMENT*, 44, no. 1 (2009).pp 95-112.

Roger W. Haines, O. Lewis Wilson, "HVAC System Design Hand Book "4TH Edition, 2003 Mc Grawhill.

R.A. Pitarma, J.E. Ramos, M.E. Ferreira, M.G. Carvalho, (2004) "Computational fluid dynamics: An advanced active tool in environmental management and education. *Management of Environmental Quality*.15.(2).pp.102 - 110

Robert N. Meroney 2009 CFD Prediction of Airflow in Buildings for Natural

Ventilation. *11th Americas Conference on Wind Engineering.* San Juan, Puerto Rico

Sharp G. 2007. A comprehensive review of the indoor environmental quality and energy impacts of dynamically varying air change rates at multiple laboratory facilities. In: *Labs21 2007 Annual Conference, North Charleston, USA, October 2-4, 2007*.

Sandru E. and Ouyang X. 2005. Planning and designing laboratory ventilation systems for the safety of the users and protection of the environment. In: *Proceedings of the 10th International Conference on Indoor Air Quality and Climate-Indoor Air 2005.4.*

Wei Cai, Danjun Wang, Xiaodong Wen, Xubo Yu (2010) Indoor Air Quality Assessment in an Art Gallery with an HVAC System

Lin Zhang, Jiang Feng, Chow TT, Tsang CF, Lu WZ. *CFD analysis of ventilation effectiveness in a public transport interchange*. Building and Environment, 41(3), 2006, 254-261.